

LOW COST POWER SEMICONDUCTOR
MODULE WITHOUT SUBSTRATE

PRIORITY STATEMENT

This application is a divisional of U.S. Patent Application Serial No. 09/758,822, filed January 11, 2001 by William Grant, entitled Low Cost Power Semiconductor Module Without Substrate which is application relates and claims priority to a United States provisional application, Ser. No. 60/175,802, entitled Low Cost Power Semiconductor Module Without Substrate, filed in the United States Patent and Trademark Office on January 12, 2000.

BACKGROUND OF THE INVENTION

This invention relates to power modules and more specifically relates to a low cost 3 phase inverter module which has no substrate for the power semiconductor die.

Power semiconductor modules are well known and are widely used. Typically, a plurality of semiconductor die, such as MOSgated devices, thyristors or diodes in various combinations are mounted on a substrate heatsink, such as an IMS (insulated metal substrate) or other substrate and are electrically connected through the substrate, and/or by wire bonds, to form a particular circuit. A printed circuit board containing low power control components is also supported by the module. Power and control terminals may then extend from an insulation housing which carries the substrate.

Substrates used to carry the power die constitute a significant part of the cost of power modules, and therefore they are limited to the smallest possible area. It

would be desirable to reduce the cost of such modules while permitting appropriate thermal management and electrical insulation:

SUMMARY OF THE INVENTION

5 In accordance with the invention, the power die are mounted directly on lead frame extensions of a lead frame which is insert molded within and supported by the module insulation housing. A heat conductive insulation layer underlies the lead frame elements to insulate it from a heat sink support for the module. No added IMS or other substrate is used, thus reducing the cost of the module.

10 In a preferred embodiment, the module is a three phase inverter circuit for automotive application for example, for electric power steering motors. However, any other desired circuit can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a top view of a lead frame which can be used with the present invention.

15 Figure 2 is a cross-section of the lead frame of Figure 1 taken across section line 2-2 in Figure 1.

Figure 3 is a perspective view of the module of the invention, before its interior is sealed with insulation plastic.

20 Figure 4 is another perspective view of the module of the invention after its interior is filled.

Figure 5 is a top view of the module of Figure 4.

Figure 6 is a side view of Figure 5.

Figure 7 is an end view of Figure 5.

25 Figure 8 is a circuit diagram of an exemplary module circuit which can be formed by the module.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring first to Figure 8, there is shown an exemplary electrical circuit diagram of a 3 phase inverter circuit which could have application to automotive uses particularly to electric power steering. Thus, terminals 20 and 21 are d-c terminals which could be connected to the automobile battery and output terminals U, V and W are 3 phase output terminals which can be used to power ac motors, or, with suitable rectification; dc motors, such as dc brushless motors, that are typically found within the automotive system. A conventional three phase inverter circuit is shown. An ASIC and other control circuit components for the MOSFETs S_1 to S_6 may also be provided to operate power MOSFETs S_1 to S_6 in a conventional sequence. The instant invention is particularly suited for low voltage applications. The die of the present invention are rated from 30 to 75 volts and are size 4.0 to 6 die as sold by the International Rectifier Corporation. Higher or lower voltage rates may also be used. For example, voltage rates of up to 1000 volts, or as low as 10 volts may be used.

While power MOSFETs S_1 to S_6 are shown as N channel devices, complementary N and P channel MOSFETs could be used.

In conventional modules, the circuit of Figure 8 is commonly formed by employing unpackaged MOSFET die which are mounted on an IMS or DBC substrate and interconnected through the substrate and by wire bonds. The substrate would then be mounted within an insulation housing and terminals, such as the terminals 20, 21, U, V, W and G_1 to G_6 would extend beyond the housing surface to be available for connection.

The substrate used to mount the die within the housing according to conventional modules is expensive. In accordance with the invention, this substrate is eliminated, with the die mounted directly on the lead frame extensions of the terminals. Note that any circuit other than an inverter can be formed, and that any

type of die or mix of die, such as N and P channel MOSFETs or IGBTs, diodes, thyristors and the like can be used and enjoy the benefits of the invention.

Figures 1 to 7 show a preferred embodiment of the invention for housing the 3 phase inverter circuit of Figure 8. Note that the same identifying numeral or letter is used in all drawings to identify the same part.

Figure 1 shows one segment of an elongated conductive, stamped lead frame which can be used with the invention. A plurality of such segments are provided in the usual manner. The various segments of the lead frame are held together by webs which will be stamped out after parts are mounted on the lead frame and wire bonded and the lead frame segments are singulated. One half of the lead frame provides terminals U, V and W which are connected to large pad areas 30, 31 and 32 respectively. These pads 30, 31 and 32 will receive the MOSFET die S4, S5 and S6 respectively. The other half of the lead frame has terminals 20 and 21 and a common drain pad 33. Terminal 21 is also connected to a source pad area 34. Die S1, S2 and S3 are connected to pad 33. Die S1 to S6 are vertical conduction MOSFET die having metallized bottom drain electrodes and a top source and gate electrode. The bottom drain electrodes may be soldered or otherwise connected, as by a silver loaded conductive epoxy, to the enlarged lead frame pad regions 30, 31, 32 and 33.

After the die S1 to S6 are fixed in place, they may be wire bonded, as shown in Figure 3 to complete the circuit of Figure 8. Thus, as shown in Figure 3, source bond wires 40 connect the pads 30, 31 and 32 to the source electrodes of die S1, S2 and S3 respectively; and source bond wires 41 connect the source electrodes of die S4, S5 and S6 to pad 34 and d-c terminal 21. Note that these bonds can be made after mounting of the lead frame in its housing.

Thus, after the die S1 to S6 are bonded to their various lead frame pads, the lead frame is insert molded in an insulation housing 50 and the lead frame bridging

sections (exterior of the dotted line in Figure 1) are removed to separate the pads from one another and the lead frames are singulated.

Alternatively, the lead frame may be first insert molded in the insulation housing 50, and the lead frame bridging sections removed, thereby singulating the pads from one another. Then, the die S1 to S6 may be bonded to their various lead frame pads, and wire bonded to one another.

In either case, the lead frames are supported by the housing 50 after lead frame trimming, with conductors U, V, W, 20 and 21 extending beyond the periphery of housing 50. Housing 50 may be preferably a thermally conductive insulation material which can electrically isolate conductive lead frame pads and a heat sink, on which the module may be mounted, from one another. The housing 50 need not, however, be made from thermally conductive material to reduce the cost of the module. For example, housing 50 may be a QUÉSTRA plastic made by DOW chemical, or a suitable PPA such as the one made by Amoco and sold under the mark AMODEL.

Housing 50 will have windows 51, 52, 53 and 54 to expose the top surfaces of pads 32, 31, 30 and 33 respectively to provide access to die S1 to S6 for the die bonding operation. A rim 60 is integral with and surrounds the housing 50 and bolt-down openings 61, 62, 63, 64 are provided at the housing corners. A bottom layer 70 of a thin insulation material extends fully across the bottom of the housing 50 and acts to electrically isolate the pads 30, 31, 32, 33 and 34 from one another and from the users heat sink on which the housing is mounted. Note that lead frame pads act to conduct thermal energy generated by the die S1 to S6 through the lead terminals and to the thermally conductive insulation layer, which may be placed in contact with a heat sink. A large percentage of the thermal energy is dissipated through the thermally conductive insulation layer, and the remainder may be dissipated through the lead terminals.

As next shown in Figure 3 printed circuit boards 80 and 81 which carry control terminals G1 to G6 (Figures 4 and 5) and related Kelvin (source) terminals and wire bond terminals therefor are fixed to the top opposite platform end surfaces of the housing 50 and appropriate wire bonds can be made.

5 After all wire bonds are made, the interior of rim 60 of housing 50 may be filled by a suitable silastic (Figures 4 and 5), or an epoxy or the like.

 A separation means 90 may then be disposed over the rim. The separation means may be rigid, and may allow the terminals to pass through. The separation means may be a blank circuit board that is capable of receiving electronic
10 components. A circuit board containing components for the control of the inverter circuit may then be disposed over the separation means 90. Due to its rigidity, the separation means keeps the terminals aligned for engagement with the circuit board containing the control components.

 Note that the module of Figures 1 to 7 has no separate substrate for receiving
15 the die S1 to S6 and, therefore has a reduced expense.

 Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.